The Influence of Atmospheric Stability on the Cloud Droplet Effective Radius as Determined by Ground-Based Remote Sensing

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Introduction

- Expansion of our previous study
  - Kim *et al*., 2003, *J. Geophys. Res*., **108**, 4730
  - Cases over a three year period
- Goals
  - Examine the robustness of the conclusions of our previous study
  - Identify meteorological influences in observed variability of droplet effective radius, r_e

Cloud Droplet Size Distributions in Low-Level Stratiform Clouds

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(Manuscript received 29 May 1998, in final form 10 February 1999)

Table 3. Summary of results in Tables 1 and 2, listing mean values and standard deviations of various microphysical quantities for marine and continental clouds.

	Marine	Continental
$N_{t,obs}$ (cm^{-3})		
mean	74	288
std dev	45	159
$D_{m,obs}$ (μm)		
mean	14.2	8.2
std dev	3.4	3.9
$\sigma_{v,obs}$ (μm)		
mean	5.8	3.1
std dev	2.0	1.2
LWC_{obs} ($g\ m^{-3}$)		
mean	0.18	0.19
std dev	0.14	0.21

Number Density

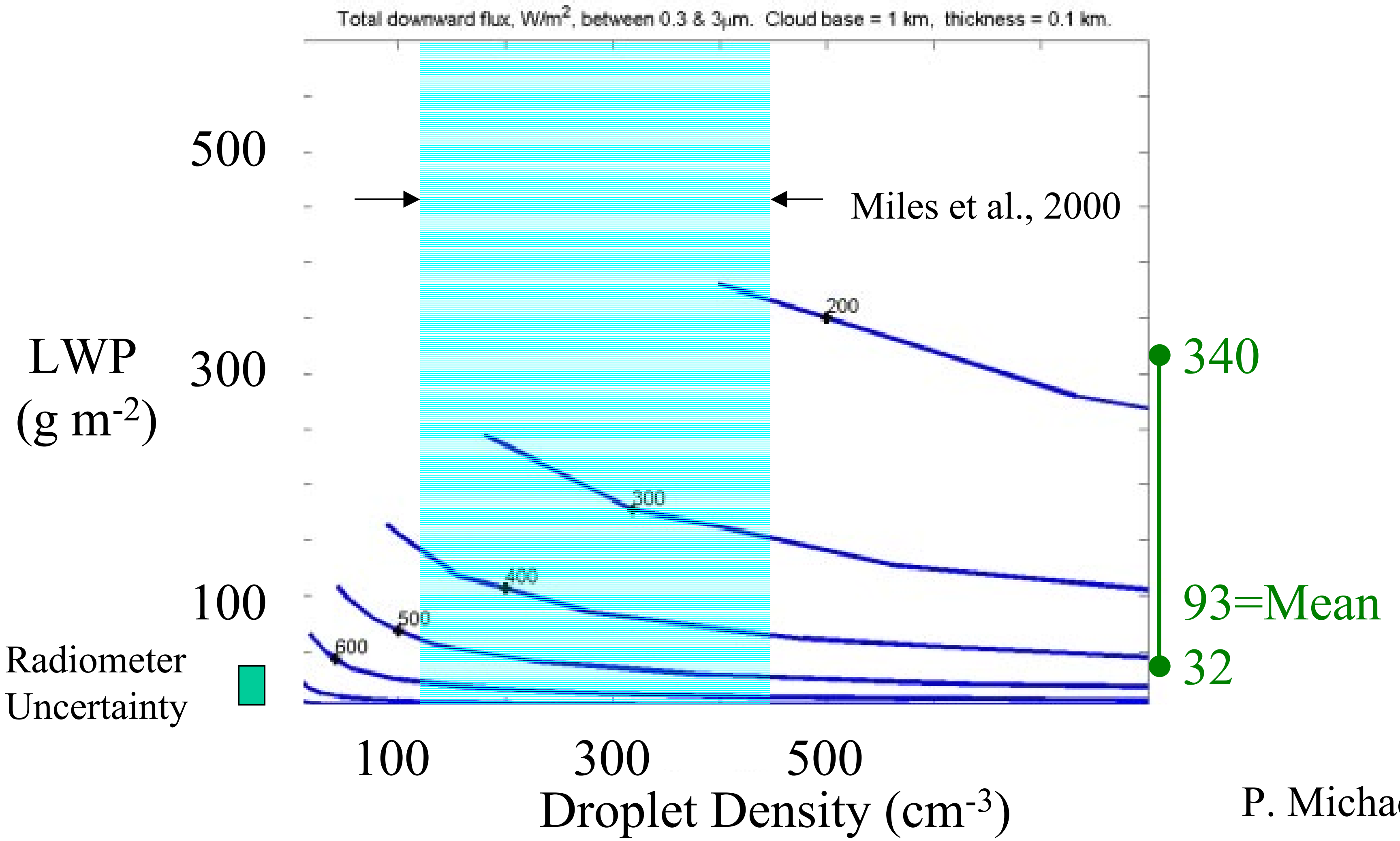
Mean and Standard Deviation

Continental

288 cm^{-3}

159 cm^{-3}

Sensitivity of Downwelling Shortwave Radiation to N_d and LWP



P. Michael

Technique

$$Q_e \approx 2$$

$$if$$

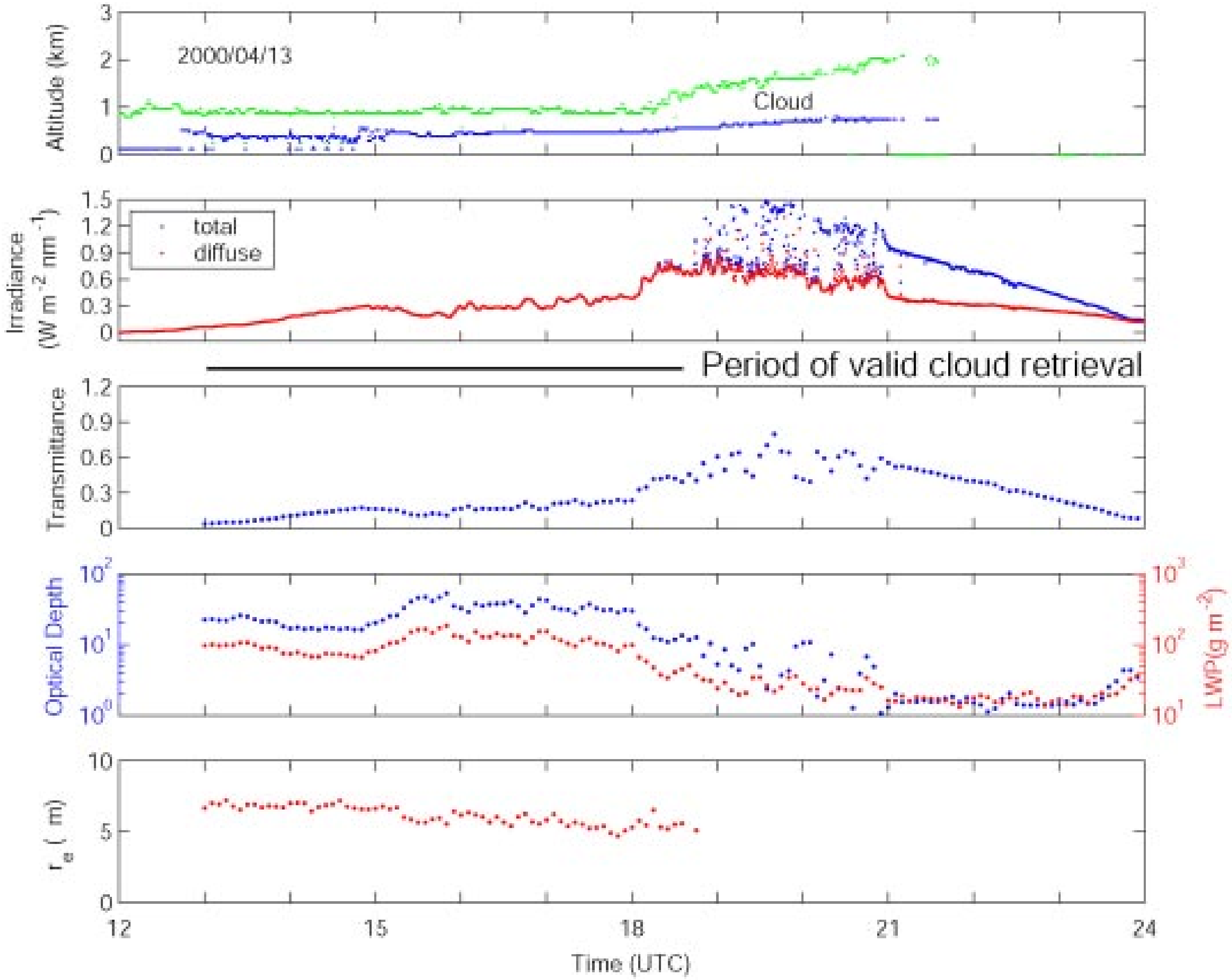
$$r >> \lambda$$

$$r_e = \frac{3}{2\rho_w}\left(\frac{L}{\tau_c}\right)$$

- Mie scattering properties depend of cloud droplet radius
- Iterative procedure based on Min and Harrison, 1996a,1996b
- Most important of these dependencies is the variation of the extinction efficiency

GROUND BASED REMOTE SENSING OF CLOUD PROPERTIES

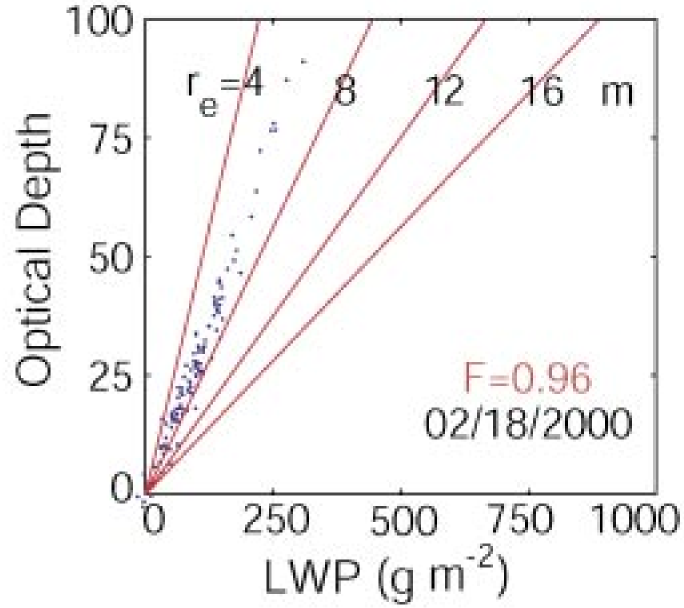
North Central Oklahoma, April 13, 2000 ĐLocal time = UTC - 6



Kim, Schwartz, Miller, and Min, JGR, 2003

CLOUD OPTICAL DEPTH VS. LIQUID WATER PATH

North Central Oklahoma, 2000



Kim, Schwartz, Miller, and Min, JGR, 2003

Optical depth is highly correlated with and strongly dependent on liquid water path.

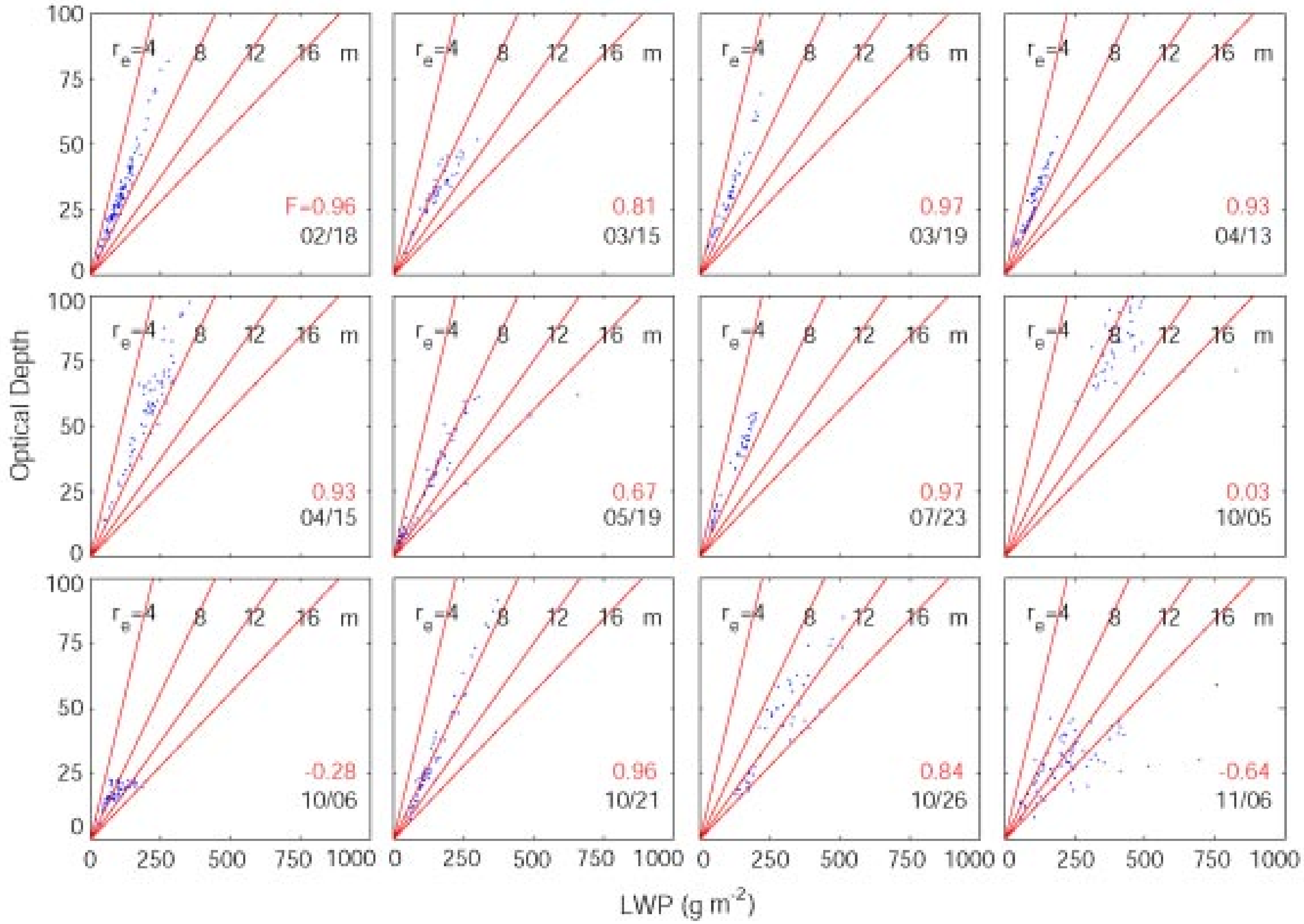
Tight cluster of points about a diagonal line through the origin is indicative of constant effective radius over the day.

Slope is inversely proportional to effective radius.

F, fraction of variance accounted for by regression = 96%.

CLOUD OPTICAL DEPTH VS. LIQUID WATER PATH

North Central Oklahoma, 2000



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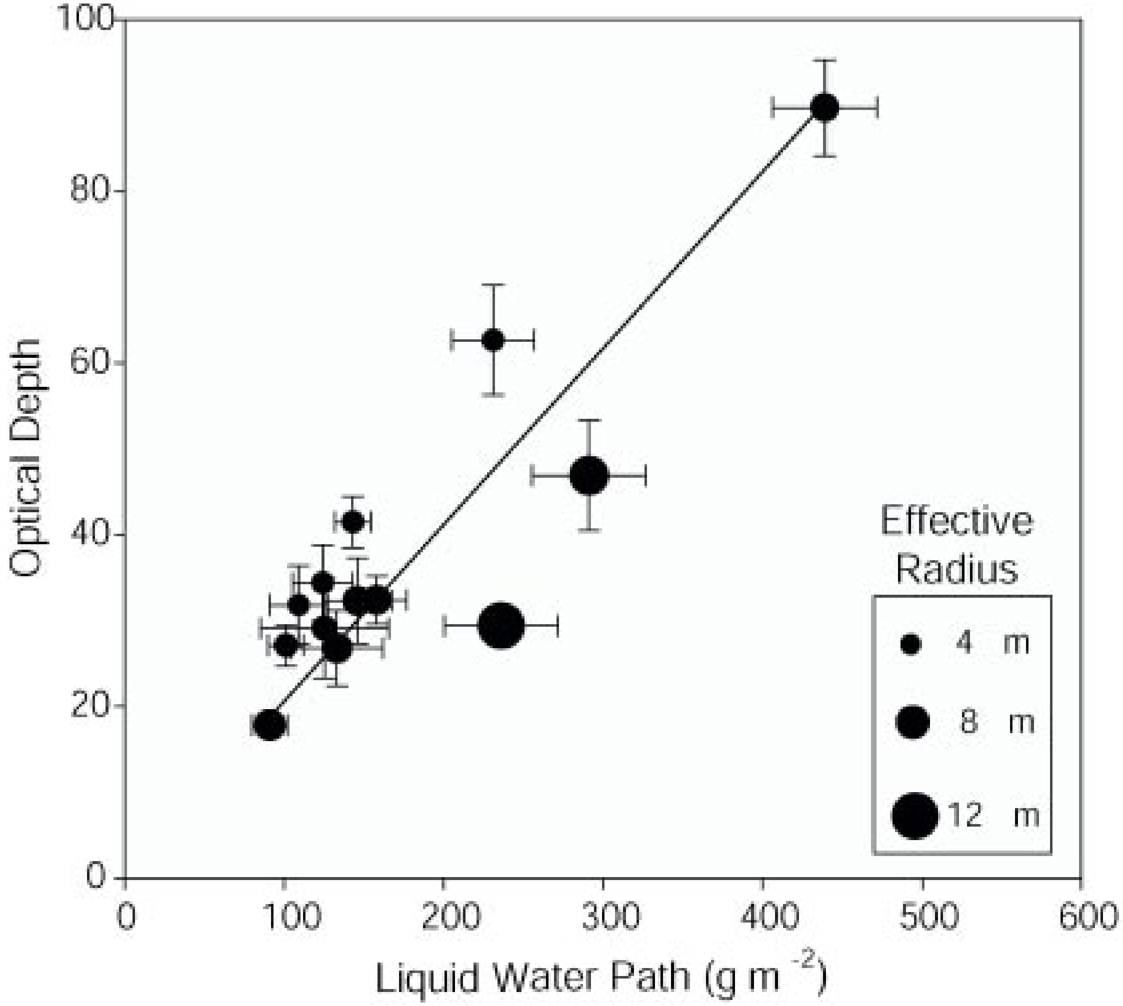
F, fraction of variance accounted for by regression, mainly > 80%.

CLOUD OPTICAL DEPTH VS. LIQUID WATER PATH

North Central Oklahoma, 2000, aggregated by days



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Fraction of variance accounted for by regression, 74%.

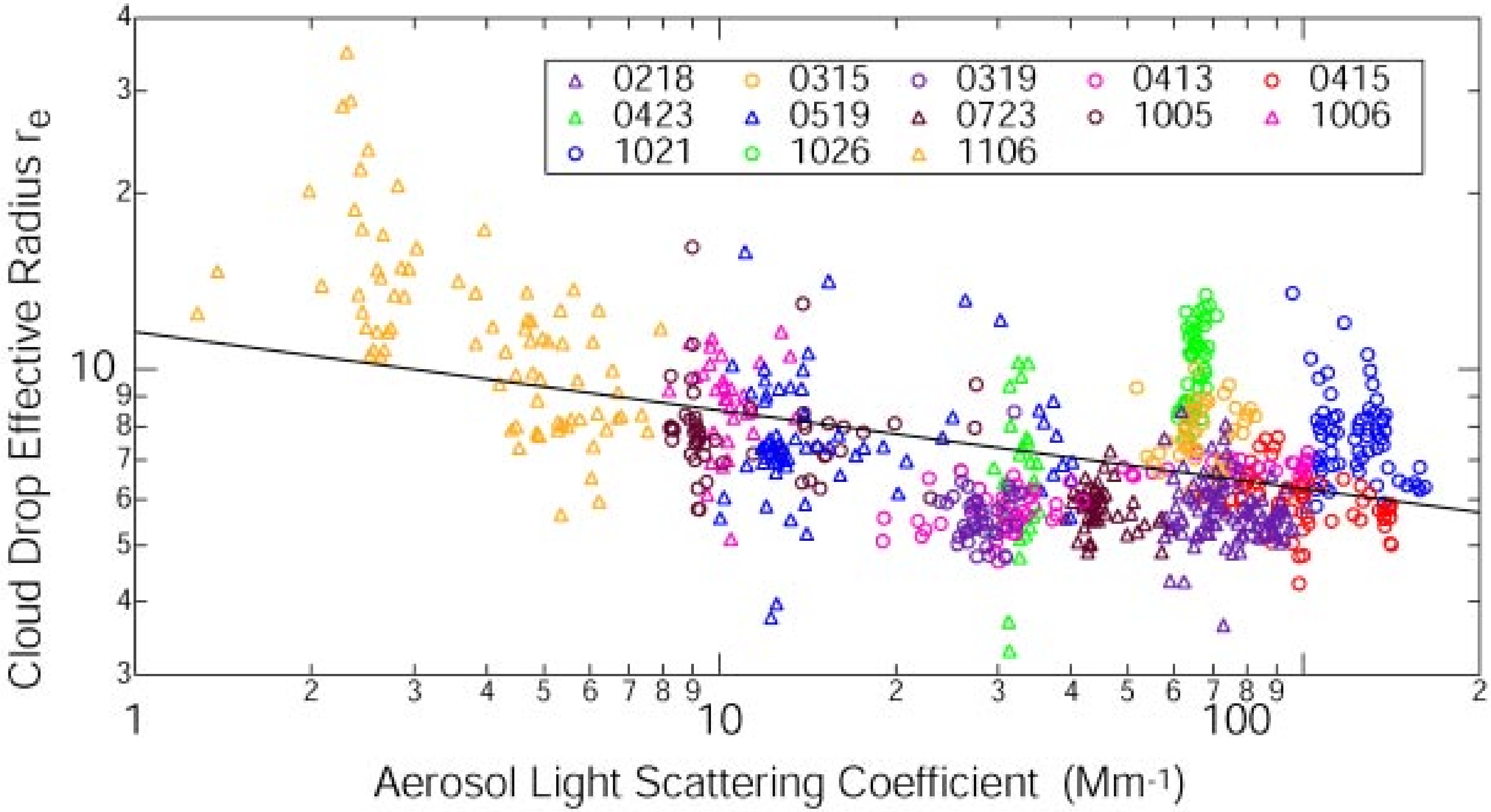
Days with smaller radii have a greater optical depth for a given LWP

CORRELATION OF CLOUD DROP EFFECTIVE RADIUS AND AEROSOL LIGHT SCATTERING COEFFICIENT

North Central Oklahoma

All days in 2000 meeting complete overcast criterion

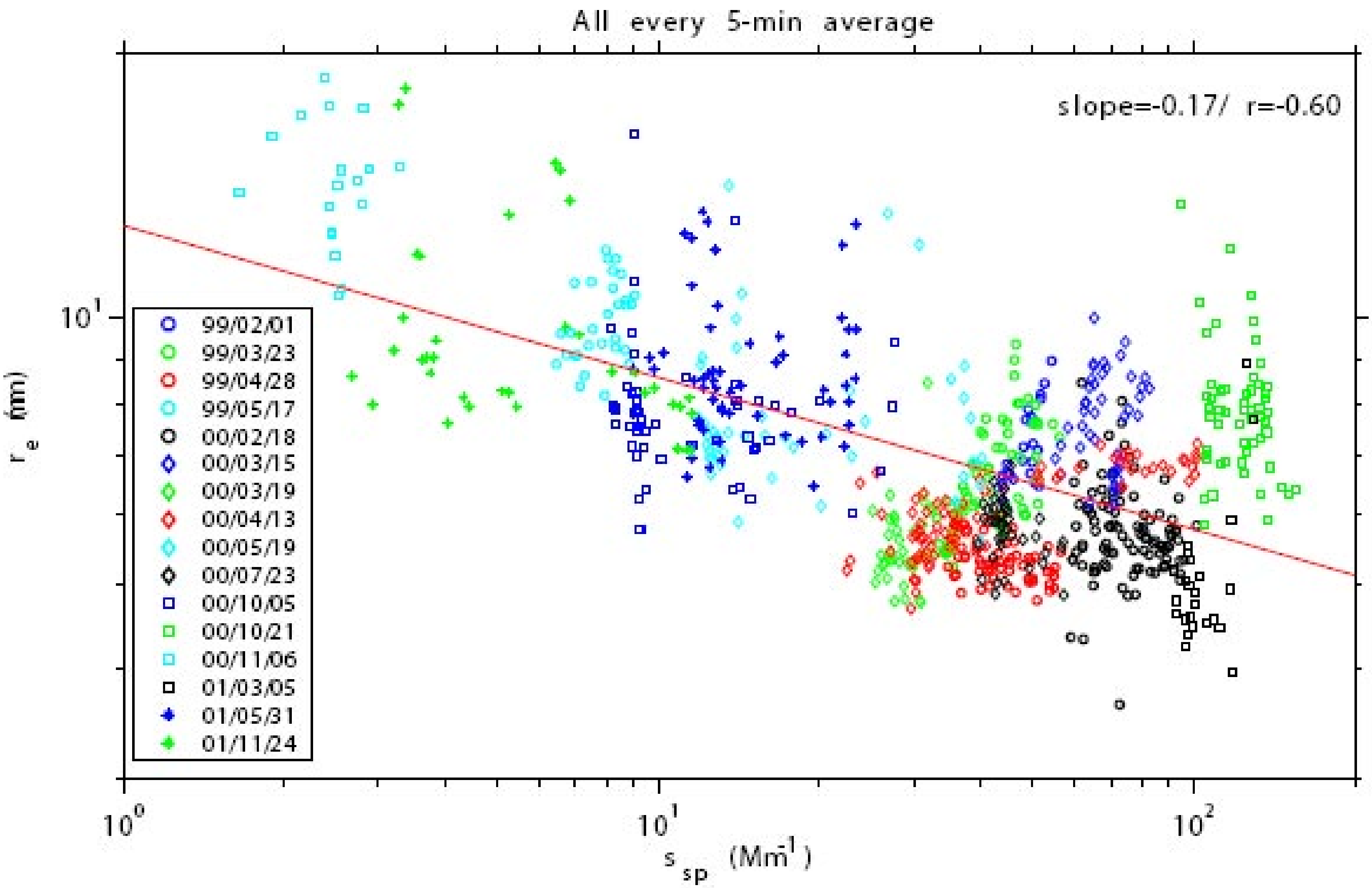
$R^2 = 0.24$



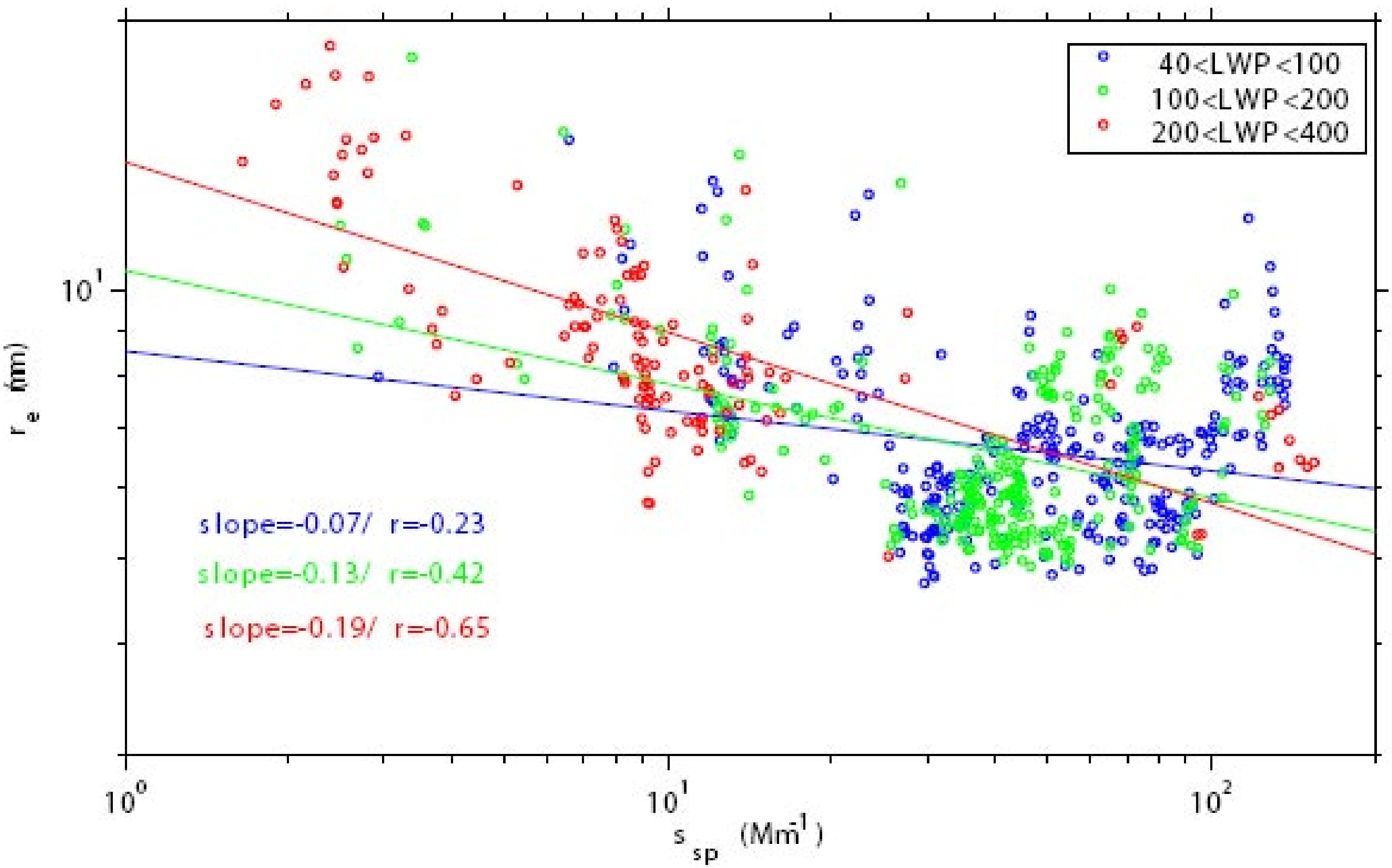
Kim, Schwartz, Miller, and Min, JGR, 2003

Conclusions of Indirect Effect Study at SGP

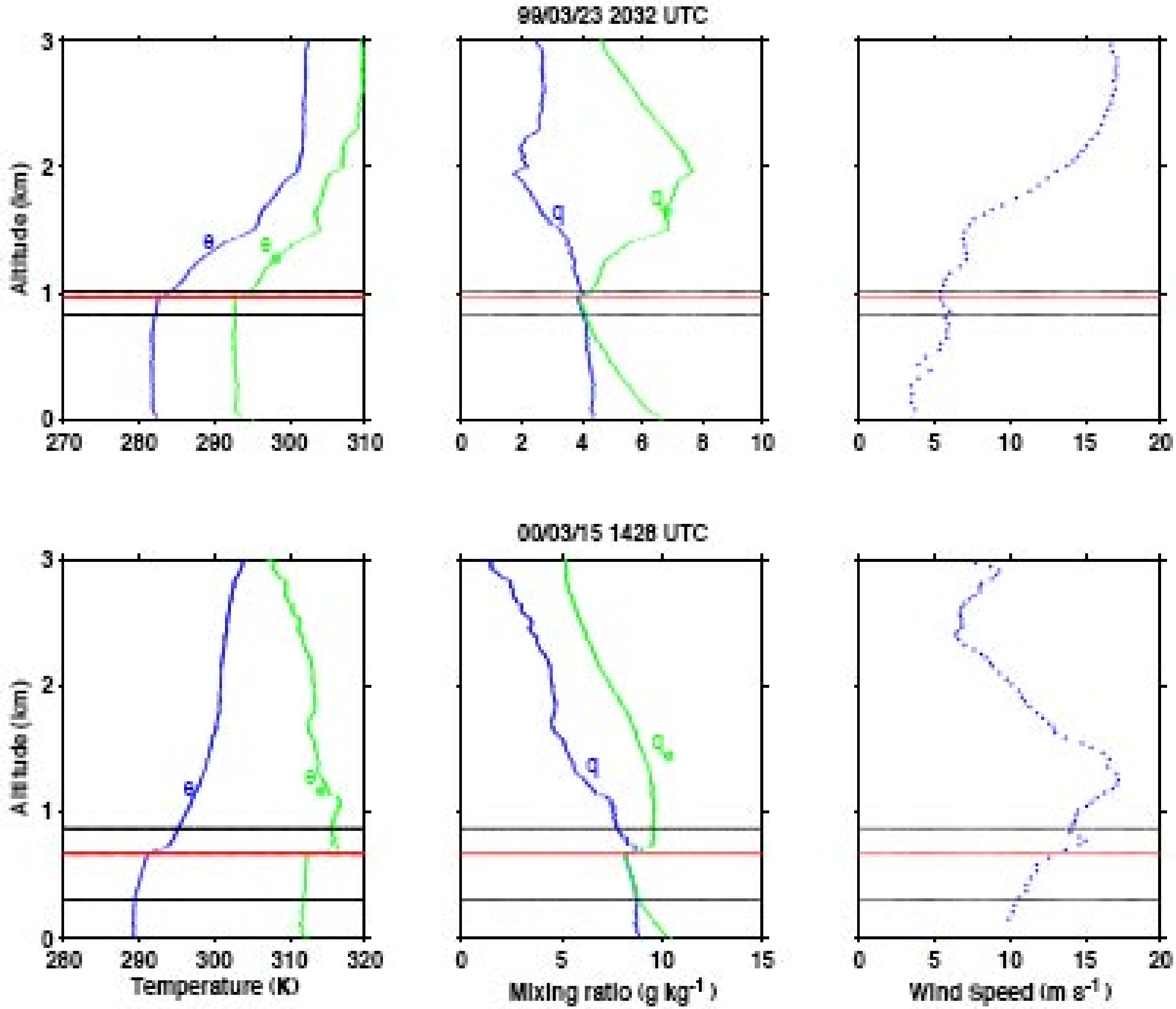
- Dominant influence on cloud optical depth, τ_c, in liquid boundary layer stratus is the Liquid Water Path (LWP), which accounts for 63% of the variance in the entire data set and up to 97% on a given day.
- Effective radius, r_e varies little during a given day, but varies from 5.6 to 12.3 μm from day to day.
- Aerosol light scattering at the surface accounted for 24% of the variance in r_e in the entire data set.



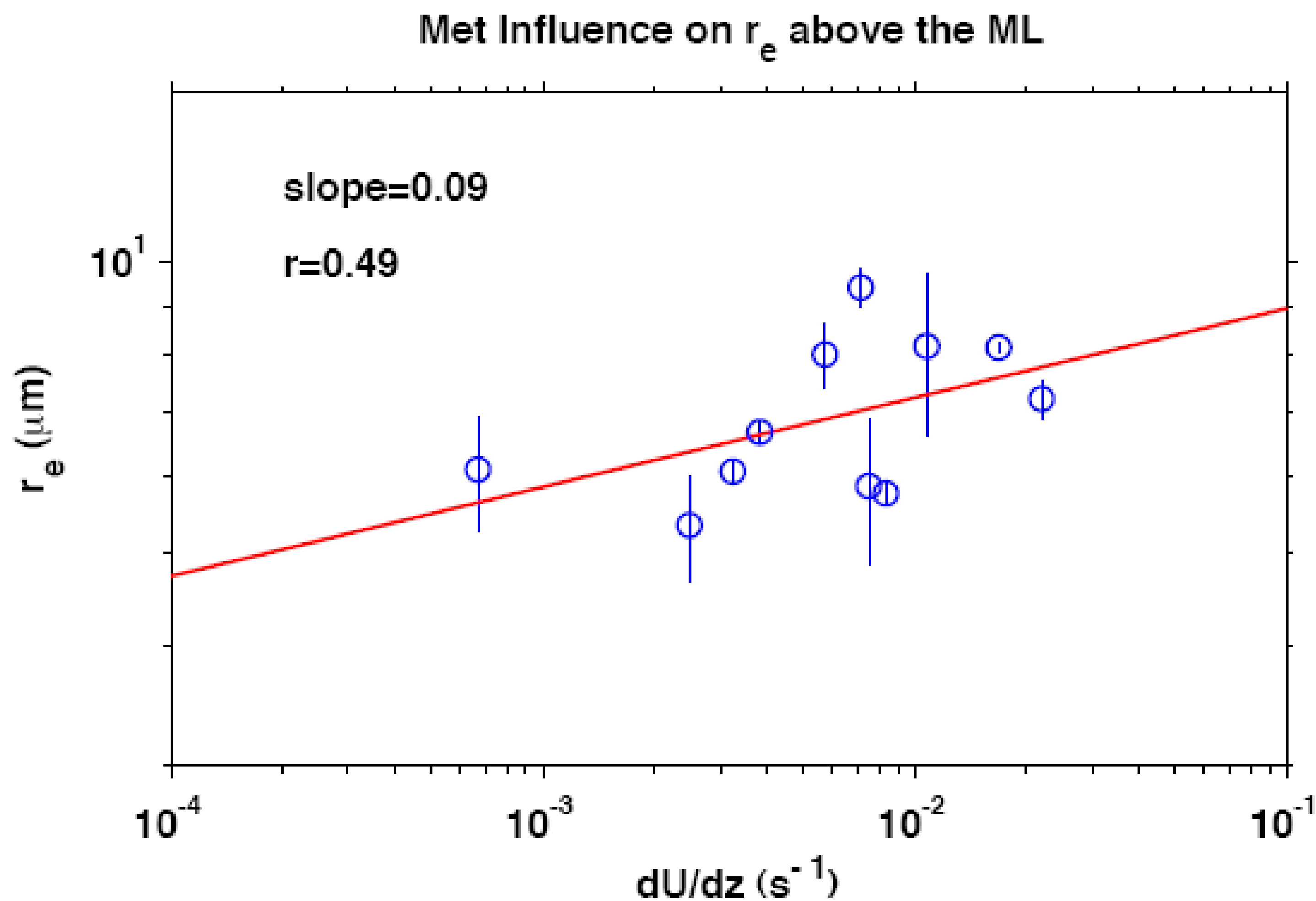
All every 5-min average
slope=-0.17/ r=-0.60
99/02/01
99/03/23
99/04/28
99/05/17
00/02/18
00/03/15
00/03/19
00/04/13
00/05/19
00/07/23
00/10/05
00/10/21
00/11/06
01/03/05
01/05/31
01/11/24
10^1
r_e (mm)
10^0
10^1
10^2
s_{sp} (Mm^{-1})



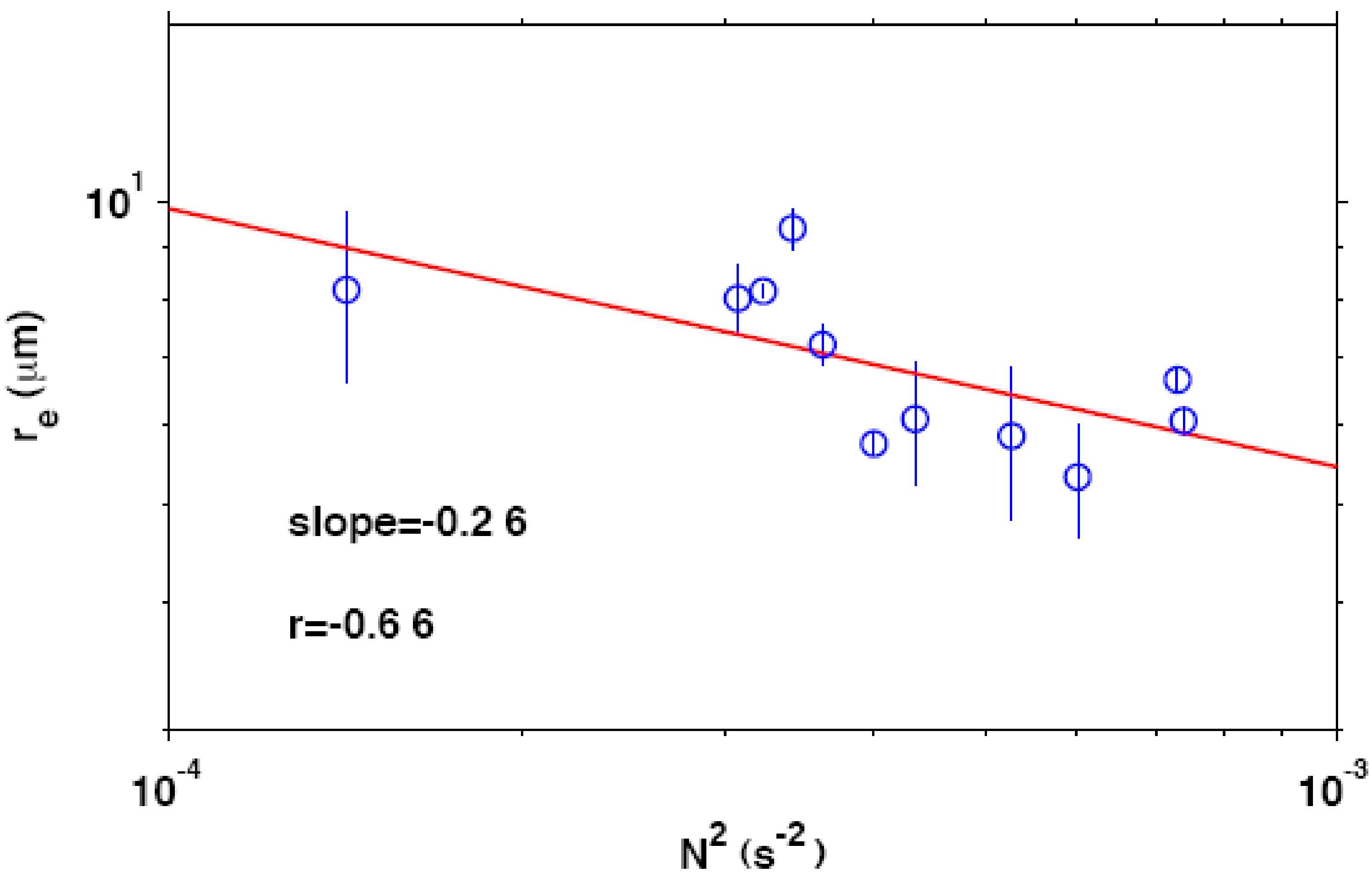
40<LWP<100
100<LWP<200
200<LWP<400
slope=-0.07/ r=-0.23
slope=-0.13/ r=-0.42
slope=-0.19/ r=-0.65
r e (μm)
s sp (Mm-1)
10^0
10^1
10^2



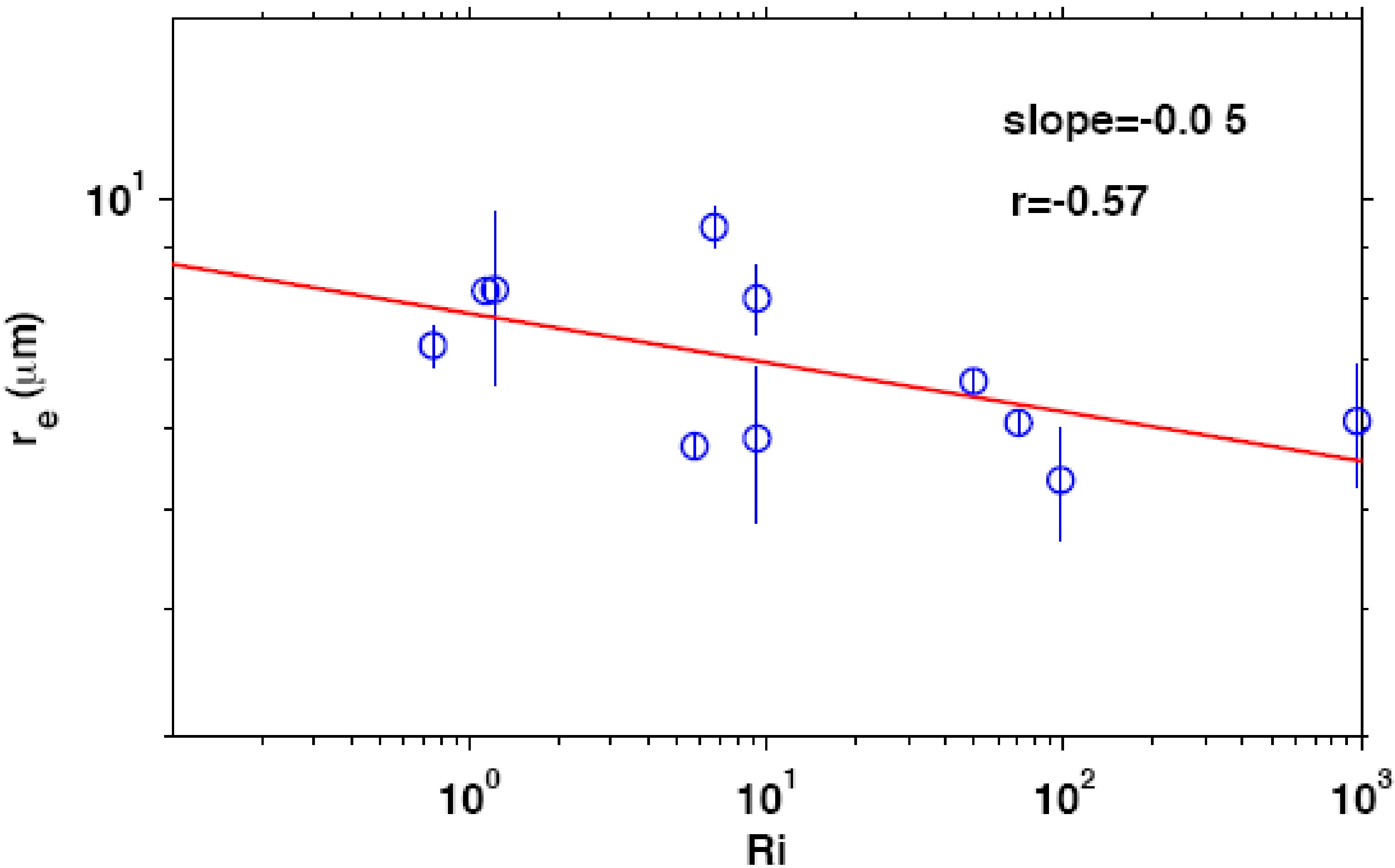
99/03/23 2032 UTC
00/03/15 1428 UTC
Altitude (km)
θ
θe
q
qe
Temperature (K)
Mixing ratio (g kg-1)
Wind speed (m s-1)



Met Influence on r_e above the ML
slope=0.09
r=0.49
r_e (μm)
10^1
10^-4
10^-3
10^-2
10^-1
dU/dz (s^-1)



r_e (μm)
10^1
slope=-0.2 6
r=-0.6 6
10^{-4}
10^{-3}
N^2 (s^{-2})



slope=-0.0 5
r=-0.57
10^1
r_e (μm)
10^0
10^1
10^2
10^3
Ri

Conclusions of Expanded Study

- Aerosol light scattering at the surface accounted for 36% of the variance in r_e in the entire data set, as compared to 24% in previous study.
  - Suggests statistical approach to quantifying indirect aerosol effects
- Clouds with 200 < LWP < 400 g m^{-2} exhibit largest effects (42% of variance in r_e is explained).
- Relatively strong relationship between N^2 and r_e (43% of variance in r_e is explained).
  - Smaller cloud droplets are correlated with higher stability at the inversion